

REMARKS

This is in response to the Office Action dated April 4, 2002. Before discussing the claims and how they distinguish over the cited art, perhaps it might be helpful to review features of Applicant's invention.

Referring to FIG. 2, as described in the patent application, if the computed exotherm  $T_{exo}$  exceeds a threshold level  $T_{exo\_thres}$ , the light-off temperature,  $T_{lo}$ , (i.e., the temperature produced by the upstr sensor 20 when the computed exotherm  $T_{exo}$  exceeds the threshold level  $T_{exo\_thres}$ ) is detected and such light-off signal  $T_{lo}$  is passed through a gate 30 to a subtractor 32. Gate 30 is an enabled gate to close temporarily when its enabling input exhibits a rising edge from negative to positive; otherwise it is open. This light-off temperature,  $T_{lo}$  which passes through gate 30 when such gate is temporarily closed, is compared with the light-off temperature expected for the catalyst 24 when such catalyst 24 was green; i.e., an expected light-off temperature  $T_{lo\_exp\_green}$ . This expected light-off temperature,  $T_{lo\_exp\_green}$ , is a function of total exhaust flow. Thus  $T_{lo\_exp\_green}$  (i.e.,  $T_{CAT\_OPTIMUM}$ ) as a function of total exhaust flow is stored in a look-up table 35. The table 35 is fed the actual total exhaust flow by a sensor disposed in the engine intake air system. The output of the look-up table 35 is thus the light -off temperature expected for a green catalyst, i.e.,  $T_{lo\_exp\_green}$ . This temperature  $T_{lo\_exp\_green}$ , along with the actual light-off temperature  $T_{lo}$  of the catalyst 24 (which was passed through gate 30) are fed to the subtractor 32. The subtractor 32 computes  $T_{lo\_diff} = T_{lo} - T_{lo\_exp\_green}$  (i.e., the difference between the actual light-off temperature of catalyst 24 and the light-off temperature expected for a green catalyst). Thus,  $T_{lo\_diff}$  is, as described above, a function of the aging of the catalyst 24 and particularly the effect of aging of the catalyst 24 on the optimum conversion temperature  $T_{CAT\_OPTIMUM}$  (FIG. 1)

This difference  $T_{lo\_diff}$  is used to compute  $f2$  for multiplication with  $f1$  produced by the look-up table 27 and thereby produce the correct control signal on line 19 for the HC injector 18.

More particularly, the function  $f_2$  for a green catalyst must be shifted as described above in connection with FIG. 2 so that  $f_2$  produced by a calculator 39 is equal to  $f_2$  where  $f_2$  is the curve 17 of FIG. 3 shifted in temperature  $T_{lo\_diff}$ , here 20 degrees C to produce curve 19 in FIG. 3.

To put it another way,  $T_{lo\_diff} = T_{lo} - T_{lo\_exp\_green}$  (i.e., where  $T_{lo}$  is the current light-off temperature of the catalyst 24 and  $T_{lo\_exp\_green}$  is the light-off temperature of the catalyst prior to its aging). The function multiplied by  $f_1$  in multiplier 29 is  $f_2$  for a green catalyst shifted in temperature by  $T_{lo\_diff}$ . Thus, the calculator 39 produces  $f_2$  for multiplication with  $f_1$  in multiplier 29 which is a function of temperature in accordance with the curve 19 in FIG. 3 if, for example,  $T_{lo\_diff} = 20$  degrees C.

The calculator 39 includes an integration to make  $T_{lo\_diff}$  depend not only on the last recorded light-off (i.e.,  $T_{lo}$ ), but the average off the last few light-off events. Thus, the calculator computes the temperature for peak NOx conversion efficiency in accordance with  $T_{lo}(k) = T_{lo}(k+1) + k_i * T_{lo\_diff}$ , where  $k_i$  is a calibration gain less than one. Thus,  $f_2 = f_2$  for a green catalyst shifted in temperature by  $T_{lo\_diff} = T_{lo}(k+1) - T_{lo\_exp\_green}$ .

Considering now U.S. Patent No. 5,201,802 (Hirota et al.), as described beginning at column 9, lines 10 through line 55:

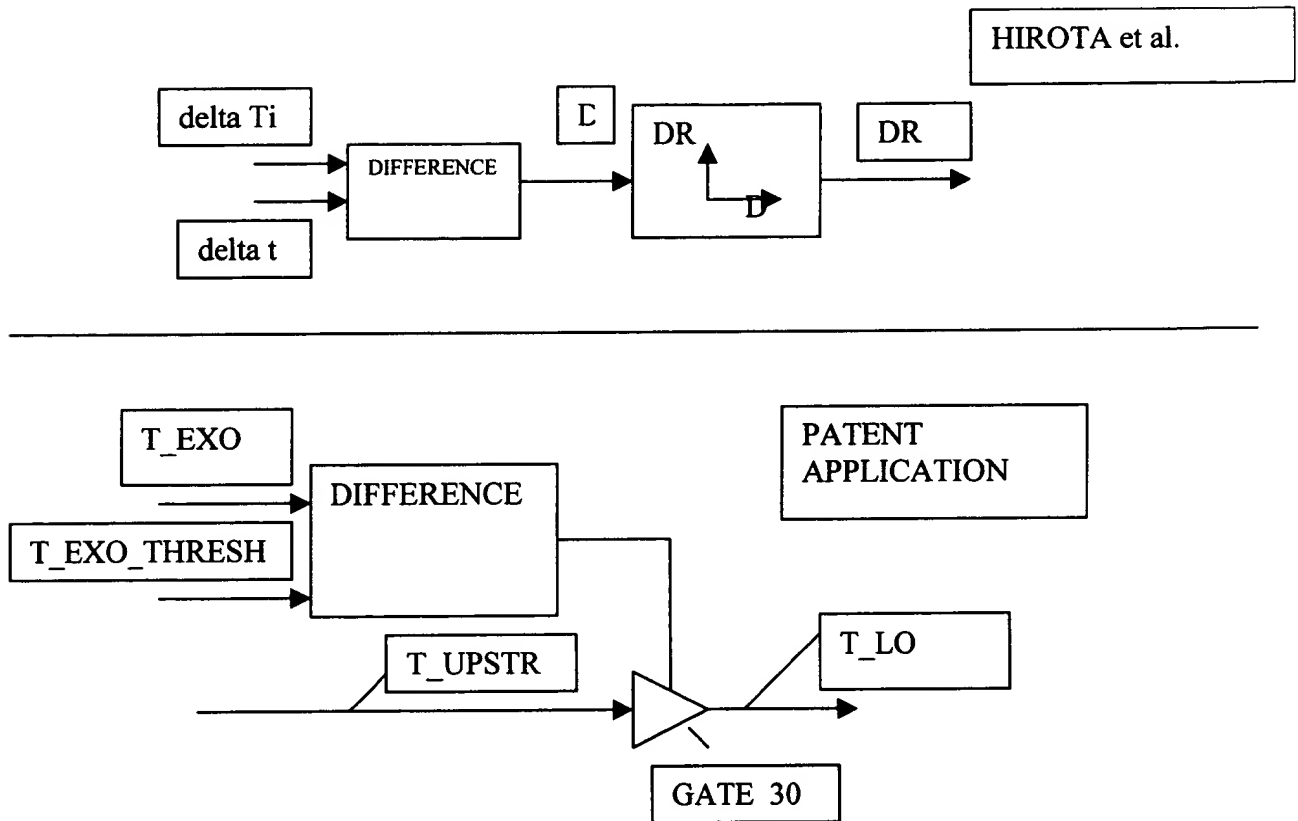
FIG. 14 illustrates a routine for determining degradation of the lean NOx catalyst 6. This routine is entered at intervals of predetermined periods of time, for example, at intervals of fifty milliseconds. At step 602, a determination is made as to whether or not the current engine operating condition is in a catalyst degradation determining condition, for example, in a warmed-up and usual running condition. If the current condition is not in the catalyst degradation determining condition, the routine returns. If the current condition is in the catalyst degradation determining condition, the routine proceeds to step 604, where the current engine load  $Q/N$  and the current engine speed  $NE$  are entered. Then, at step 606, a predetermined reference temperature difference ( $\Delta T_i$ ) between the inlet gas and the outlet gas of the lean NOx catalyst 6, which corresponds to the engine load and engine speed conditions, is read from a map of FIG. 15.

Then, at step 608, the difference between the current inlet gas temperature  $t_1$  (output of the temperature sensor 24) and the current outlet gas temperature  $t_2$  (output of the temperature sensor 20) of the lean NOx catalyst 6 is calculated

using the equation  $\Delta t = t_2 - t_1$ . Then, at step 610, a catalyst degradation function  $D$  is calculated as a difference between the current temperature difference  $\Delta t$  and the reference temperature difference  $\Delta T_i$  using the equation  $D = \Delta T_i - \Delta t$ . Then, at step 612, a catalyst degradation extent  $DR$  is calculated using a map of  $DR$  versus  $D$  map of FIG. 16. In this instance, the steps 604 through 612 and FIG. 16 constitute the means for determining degradation of the lean  $\text{NO}_x$  catalyst 6 in the third embodiment.


Then, at step 614, a lower limit  $T_1$  and an upper limit  $T_2$  of an object temperature range for the catalyst 6 are calculated based on the catalyst degradation extent  $DR$  using a map of object temperature range versus catalyst degradation extent of FIG. 17. In FIG. 17, there is a relationship between the temperatures  $T_1$  and  $T_2$  and the degradation extent  $DR$  such that the larger the value  $DR$  is, the higher the temperatures  $T_1$  and  $T_2$  are. Then, at step 616, the lower limit of the object temperature range  $T_C$  is replaced by the calculated  $T_1$  and the upper limit of the range  $T_H$  is replaced by  $T_2$ . The control of catalyst temperature is executed according to the routine of FIG. 4 which was discussed. Then, the routine proceeds to step 618, where an object HC concentration  $H_1$  is calculated using the map of  $H_1$  versus  $DR$  of FIG. 18. In FIG. 18, there is a relationship between the object HC concentration  $H_1$  and the degradation extent  $DR$  such that the larger the  $DR$  is, the higher the HC concentration  $H_1$  is. At step 620, the object HC concentration  $H_T$  is replaced by the calculated  $H_1$ . The control of the HC amount is executed using the routine of FIG. 5 which was discussed. In this instance, the steps 618 and 620 and FIG. 18 constitute the means for increasing the amount of hydrocarbons supplied to the lean  $\text{NO}_x$  catalyst 6 in the third embodiment. Further, the steps 614 and 616 and FIG. 17 constitute the means for increasing the catalyst temperature when the catalyst 6 has been degraded in the third embodiment.

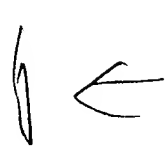
A comparison between the description above in the Hirota et al. patent and the system described by the Applicant above is summarized in the sketch below:



Thus, in Hirota et al. the difference between delta Ti and delta t provides D and D is used as an input to a lookup table to find DR. Hirota et al, does not determine an exothermic condition temperature at an output of the catalyst when the temperature difference is determined to exceed the threshold. With the present invention, on the other hand, the difference between T\_EXO and T\_EXO\_THRESH is used to detect a light-off condition and when such light-off condition is detected such detection serves as a gating signal to gate the temperature an the light-off temperature, T\_lo, (i.e., the temperature produced by the upstr sensor 20 when the computed exotherm T\_exo exceeds the threshold level T\_exo\_thres) through the gate 30 to a subtractor 32. Thus, the gate 30 is an enabled gate to close temporarily when its enabling input exhibits a rising edge from negative to positive; otherwise it is open. This light-off temperature, T\_lo which passes through gate 30 when such gate is temporarily closed, is compared with the light-off

temperature expected for the catalyst 24 when such catalyst 24 was green; i.e., an expected light-off temperature  $T_{lo\_exp\_green}$ .

Referring now to the claims, claim 1 includes injecting the hydrocarbon into the engine in accordance with detection of a light-off event. Such process is not described in King et al., Kilbe et al, not Hirota et al. 

Claim 4 includes "(b) detecting a temperature of an output of the catalyst in response to the detected exothermic reaction". Such process is not described in King et al., Kilbe et al, not Hirota et al. 

Claim 5 includes:

- (c) determining an exothermic condition temperature at an output of the catalyst when the temperature difference is determined to exceed the threshold;
- (d) comparing the determined exothermic condition temperature with an exothermic condition temperature expected from the catalyst at a time prior to the determined exothermic condition temperature; and
- (e) modifying the injected hydrocarbon in accordance with said comparison. (emphasis added)

Thus, referring to FIG. 2. the determined exothermic condition temperature ( $T_{UPSTR}$  at light-off (i.e.,  $T_{LO}$ ) is compared with  $T_{LO\_EXP\_GREEN}$ . Hirota et al, does not determine an exothermic condition temperature at an output of the catalyst when the temperature difference is determined to exceed the threshold; comparing the determined exothermic condition temperature with an exothermic condition temperature expected from the catalyst at a time prior to the determined exothermic condition temperature; and modify the injected hydrocarbon in accordance with said comparison, as claimed in set forth in claim 5.

Claim 5 has been amended to correct an error to thereby provide proper antecedent basis for "comparison".

Claim 6 includes:

- (b) comparing the temperature difference with a predetermined temperature threshold;
- (c) determining an exothermic condition temperature at an output of the catalyst when the temperature difference is determined to exceed the threshold. (emphasis added).

Claim 7 has been amended to point out that processor being programmed to:

- compare a difference in the common parameter detected by the pair of sensors with a predetermined threshold;
- determine an exothermic condition at an output of the catalyst when the difference in the common parameter is determined to exceed the threshold;
- compare the determined exothermic condition with an exothermic condition expected from the catalyst at a time prior to the determined exothermic condition; and
- modify the injected hydrocarbon in accordance with said last-mentioned comparison.

Such is not described in the cited references for reasons set forth above.

Claim 8 has been amended to correct an improper claim dependency and to provide proper antecedent support for "sensor".

Claim 9 points out that the control signal is provided by steps comprising:

- comparing a difference in the common parameter detected by the pair of sensors with a predetermined threshold;
- determining an exothermic condition at an output of the catalyst when the difference in the common parameter is determined to exceed the threshold;
- comparing the determined exothermic condition with an exothermic condition expected from the catalyst at a time prior to the determined exothermic condition; and
- modifying the injected hydrocarbon in accordance with said last-mentioned comparing.

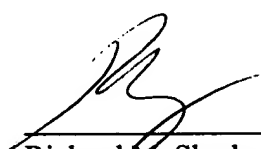
Such is not described in the cited references.

Any questions regarding this matter may be directed to the undersigned. In the event any additional fee is required, please charge such amount to the Patent and Trademark Office Deposit Account No. 50-0845.

Respectfully submitted,

Date

5/7/02

  
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Attachment: Sheets of Claims with Markings showing changes made

**CLAIMS WITH MARKINGS SHOWING CHANGES MADE**

1. A method for controlling hydrocarbon injection into an engine exhaust to reduce NO<sub>x</sub>, comprising:  
injecting the hydrocarbon into the engine exhaust in accordance with detection of a light-off event.
- ~~2. A method for controlling hydrocarbon injection into an engine exhaust to reduce NO<sub>x</sub> in such exhaust, such engine exhaust with the NO<sub>x</sub> and the injected hydrocarbon being directed to a catalyst for reaction therein, comprising:~~
  - ~~(a) detecting a temperature difference across the catalyst; and~~
  - ~~(b) injecting the hydrocarbon into the engine exhaust in accordance with the temperature difference.~~
- ~~3. A method for controlling hydrocarbon injection into an engine exhaust to reduce NO<sub>x</sub> in such exhaust, such engine exhaust with the NO<sub>x</sub> and the injected hydrocarbon being directed to a catalyst for reaction therein, comprising:~~
  - ~~(a) detecting an exothermic reaction across the catalyst; and~~
  - ~~(b) injecting the hydrocarbon into the detected exothermic reaction.~~
4. A method for controlling hydrocarbon injection into an engine exhaust to reduce NO<sub>x</sub> in such exhaust, such engine exhaust with the NO<sub>x</sub> and the injected hydrocarbon being directed to a catalyst for reaction therein, comprising:
  - (a) detecting an exothermic reaction across the catalyst; and
  - (b) detecting a temperature of an output of the catalyst in response to the detected exothermic reaction; and



(c) injecting the hydrocarbon into the reaction in accordance with the detected temperature.

5. (Amended) A method for controlling hydrocarbon injection into an engine exhaust to reduce NOx in such exhaust, such engine exhaust with the NOx and the injected hydrocarbon being directed to a catalyst for reaction therein, comprising:

- (a) detecting a temperature difference across the catalyst;
- (b) comparing the temperature difference with a predetermined temperature threshold;
- (c) determining an exothermic condition temperature at an output of the catalyst when the temperature difference is determined to exceed the threshold;
- (d) comparing the determined exothermic condition temperature with an exothermic condition temperature expected from the catalyst at a time prior to the determined exothermic condition temperature; and
- (e) modifying the injected hydrocarbon in accordance with said last-mentioned comparison.

6. A method for determining peak efficiency temperature of a catalyst in reducing NOx wherein such NOx is reduced by reacting such NOx in the catalyst with a hydrocarbon, comprising:

- (a) detecting a temperature difference across the catalyst;
- (b) comparing the temperature difference with a predetermined temperature threshold;
- (c) determining an exothermic condition temperature at an output of the catalyst when the temperature difference is determined to exceed the threshold.

7. (Amended) A system for controlling hydrocarbon injection into an engine exhaust to reduce NOx in such exhaust, such engine exhaust with the NOx and the injected hydrocarbon being directed to a catalyst for reaction therein, comprising:

(a) a catalyst for facilitating a reaction between the injected hydrocarbon and NO<sub>x</sub> in the exhaust;

(b) a hydrocarbon injector for injecting the hydrocarbon into the exhaust upstream of the catalyst;

(c) a detecting system comprising:

a pair of ~~detector~~ sensors each detecting a common parameter in the exhaust, one of such sensors being upstream of the catalyst and the other one of the sensors being downstream of the first sensor; and

a processor for controlling the hydrocarbon injector in response to the pair of sensors, such processor being programmed to:

compare a difference in the common parameter detected by the pair of sensors with a predetermined threshold;

determine an exothermic condition at an output of the catalyst when the difference in the common parameter is determined to exceed the threshold;

compare the determined exothermic condition with an exothermic condition expected from the catalyst at a time prior to the determined exothermic condition; and

modify the injected hydrocarbon in accordance with said last-mentioned comparison.

8. (Amended) The system recited in claim 12 7 wherein the common parameter is temperature and wherein the sensors ~~detectors~~ are temperature sensors ~~detectors~~.

9. (Amended) A processor for controlling hydrocarbon injection into an engine exhaust to reduce NO<sub>x</sub> in such exhaust, such engine exhaust with the NO<sub>x</sub> and the injected hydrocarbon being directed to a catalyst to facilitate reaction between the injected hydrocarbon and the exhaust NO<sub>x</sub>, such processor being programmed to:

provide a control signal to a hydrocarbon injector to inject the hydrocarbon into the exhaust upstream in response to output signal from a pair of sensors, each of the pair of sensors being adapted detecting a common parameter in the exhaust, one of such sensors being upstream of the catalyst and the other one of the sensors being downstream of the first sensor, such control signal being provided by steps comprising:

comparing a difference in the common parameter detected by the pair of sensors with a predetermined threshold;

determining an exothermic condition at an output of the catalyst when the difference in the common parameter is determined to exceed the threshold;

comparing the determined exothermic condition with an exothermic condition expected from the catalyst at a time prior to the determined exothermic condition; and

modifying the injected hydrocarbon in accordance with said last-mentioned comparing.

10. (NEW) A method for controlling hydrocarbon injection into an engine exhaust to reduce NOx in such exhaust, such engine exhaust with the NOx and the injected hydrocarbon being directed to a catalyst for reaction therein, comprising:

comparing a difference in a common parameter detected by a pair of sensors with a predetermined threshold, one of such sensors being upstream of the catalyst and the other one of the sensors being downstream of the first sensor;

determining an exothermic condition at an output of the catalyst when the difference in the common parameter is determined to exceed the threshold;

comparing the determined exothermic condition with an exothermic condition expected from the catalyst at a time prior to the determined exothermic condition; and

modifying the injected hydrocarbon in accordance with said last-mentioned comparison.

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11. (NEW) The method recited in claim 10 wherein the common parameter is temperature and wherein the sensors are temperature sensors.